ENGLISH TRANSLATION
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Description

Method for cleaning a particulate filter

The invention relates to a method for regenerating a particulate filter, which is mounted inside the exhaust gas channel of an internal combustion engine, filters particles out of the exhaust gas flowing inside of the exhaust gas channel and is intermittently regenerated during operation.

Modern internal combustion engines, in particular, gasoline and diesel internal combustion engines, are usually equipped with an exhaust emission control system, in order to reduce exhaust gas emissions. With the permitted emission limits being tightened more and more in all the main industrial countries, particulate filters are being used increasingly in exhaust emission control systems. Particulate filters are important especially for diesel internal combustion engines, as with these there can be comparatively large emissions of soot particulates.

A particulate filter filters out particles contained in the exhaust gas, mainly soot particulates, and stores these particles. Typically, it contains a filter element, which the exhaust gas to be filtered flows through. The choice of the porosity of the filter chosen depends on the size of the particles to be filtered out. Above a certain size, the particles are retained in the filter element of the particulate filter. Thus the particulate filter is increasingly loaded with particles. The particulate filter must be cleaned or replaced at regular intervals to avoid the particulate filter becoming blocked ("clogging-up"). This is necessary so that the particulate filter can always fulfill its function of cleaning the exhaust gas with sufficient efficiency.

A new particulate filter can replace the particulate filter, or the particulate filter used can be cleaned. Possible cleaning methods to be considered are cleaning the filter externally outside the

internal combustion engine or cleaning while the engine is in operation, which is called regeneration of the particulate filter in this invention.

The regeneration of the particulate filter can, for example, be achieved by combustion of the stored particles. To that end, the particulate filter is brought temporarily to a temperature above the ignition temperature of the particles. As soon as the ignition temperature is reached, and as long as there is sufficient oxygen concentration in the exhaust the stored particles are burned away spontaneously. As the ignition temperature is well above the usual operating temperature of the particulate filter, typically the particle filter must be actively heated up to attain this. For example, burning away soot particulates without the addition of additives requires an ignition temperature of at least 550°C. The addition of additives can reduce the ignition temperature, but this then makes it necessary to have a device for adding the additives and a control procedure for operating it.

To achieve the optimal efficiency from the particulate filter and to keep the operating costs arising from the regeneration of the particulate filter as low as possible, in the prior art, typically, the particulate filter is continuously monitored. The aim of the monitoring is to determine the optimal time for a regeneration procedure. If the time intervals between regenerations are too long, the efficiency of the particulate filter drops steeply, especially towards the end of each time interval. The increasing "clogging" of the particulate filter results in the exhaust gas flow being impeded, which causes an increase in the exhaust gas counter pressure and thus fuel consumption. On the other hand, if the time intervals between regenerations are too short, the operating costs involved are higher than necessary.

Pressure sensors can be used to monitor the particulate filter, which sensors measure the exhaust gas pressure in the exhaust gas channel upstream and downstream of the particulate filter. Monitoring methods are also possible whereby only one single pressure sensor is used, which sensor measures the pressure difference of the exhaust gas directly before and after the particulate filter. In both cases, pressure-measuring signals are fed into a control unit, which uses these to determine the pressure difference between the exhaust gas pressure upstream and downstream of the particulate filter. If the pressure difference exceeds a preset threshold value, then measures are initiated for the regeneration of the particulate filter.

The disadvantage of this procedure is, however, additional costs of material and manufacture involved with the required sensor technology. Thus the pressure sensors must either be mounted directly on the exhaust gas pipe or be connected to the exhaust gas system by means of pipes. Thereby, mounting directly onto the exhaust gas pipe is problematic, as, in this case, the pressure sensor or sensors must be designed, in particular, for high exhaust gas temperatures, for vibration load, for splash water from outside and also for stones striking from outside.

If a differential pressure sensor is used, then the sensor must be connected by pipe to the appropriate points of the exhaust gas system.

In addition, it has been found that piping and pressure sensors are prone to blocking. Such blocking can be caused by, for example, the particles contained in the exhaust gas or by other contaminants, such as oil combustion residue. Condensation water with the inherent problem of ice formation at low outside temperatures can also result in clogging up.

This is the starting point for the invention, which is based on the object of developing a method of the type presented at the beginning

in such a way that the regeneration times of the particulate filters can be determined without recourse to additional sensor technology.

This object is achieved in accordance with the invention in a first variant by measuring the air mass flow supplied to the internal combustion, which is determined at the expected air requirement of the internal combustion engine with the current operating parameters and by introducing a regeneration of the particulate filter based on a difference between air mass flow and the air requirement.

Thus the invention is based on the idea not to determine the regeneration times by means of the fall in pressure over the particulate filter in the exhaust gas channel, but by exploiting another effect that goes along with the particulate filter becoming increasingly loaded. The solution according to the invention builds on the observation that when the particulate filter becomes increasingly loaded, the exhaust gas counterpressure rises, which leads to a reduction of the fresh air mass sucked in by the internal combustion engine each working stroke. This reduction in the fresh air mass causes the air mass flow to sink in the operation of the internal combustion engine, and at the same time the maximum power sinks. Without the particulate filter's effect of raising the exhaust gas counterpressure, a higher air requirement would be expected from the internal combustion engine. Thus from the difference between the air mass flow, which is supplied to the internal combustion engine, and the air requirement expected at the current operating point, the condition of the particulate filter can be judged. Thus, advantageously, an assessment is made of the immediate effect of the clogging.

In the method according to the invention in the first variant, the air requirement is calculated on the basis of operating parameters of the internal combustion engine, e.g. using a model, and the regeneration times of the particulate filter are determined on the basis of the difference of the present volume of the measured air mass flow from the calculated air requirement. In fact if the

exhaust gas counterpressure increases because of an increasing accumulation in the particulate filter, then the air mass throughput through the internal combustion engine falls increasingly in comparison with the condition with an empty or freshly regenerated particulate filter. This effect occurs in naturally aspirated internal combustion engines and is also to be observed even more pronounced in supercharged internal combustion engines because of the turbo-superchargers' sensitivity to counterpressure.

Here, in the invention, the determination of the volume of the air mass flow includes, in particular, a direct measurement of the air mass flow as well as a measurement of a volume connected to the air mass flow, from which volume the air mass flow can then be determined.

Advantageously, the method according to the invention provides that the volume of the air mass flows supplied to the internal combustion engine is determined by an air mass measuring device mounted in a suction tract of the internal combustion engine or by a pressure sensor mounted in the intake tract of the internal combustion engine.

As a rule, a model for load detection is integrated into modern controls for internal combustion engines, which model uses different operating parameters of the internal combustion engine to determine the air requirement of such engine. Thus in the method according to the invention, there no additional requirement needed to determine the cleaning times, if the determination of the air requirement already being done for the load detection can also be used in addition to monitor the condition of the particulate filter.

In a useful development of the method according to the invention in the first variant, the particulate filter is judged to be clogged and a regeneration procedure initiated, if the difference in the present volume of the air mass flow measured from the air requirement calculated from the operating parameters exceeds a

certain predetermined threshold value. Such an assessment allows the control system to be designed especially simply.

The predetermined threshold value can, for example, be determined experimentally. Advantageously, its value then takes into account the fact that the air requirement calculated according to a load detection model and air mass flow measured in practice do not correspond completely. Thereby, it is understood that influencing variables other than the accumulation of particles in the particulate filter are also taken into consideration and included in the calculation of the air requirements of the internal combustion engine. These influencing variables, for example the ambient pressure or component tolerances, can throw the load detection system, and hence lead to the measured air mass flow being different from the calculated air requirement, when cleaning the particulate filters might be neither necessary or useful.

With the increasingly used supercharged internal combustion engines, the ambient pressure is generally measured using a suitable sensor, so that it can be taken into consideration in the load detection model without further ado. However, in the prior art, methods are also known for adapting the load detection model to the ambient pressure in suitable operating states without using an ambient pressure sensor. Adaptations to other values affecting the load detection model, such as, for example, the component tolerances mentioned, can be achieved, for example, by adapting the load research model in ranges with a well-defined particulate filter condition, for example, an empty or freshly regenerated filter.

It is understood that there is an interaction between the threshold value, which, when exceeded, will trigger a regeneration procedure of the particulate filter, and the exactitude with which further influencing variables are taken into consideration in the load

detection model. If the load detection model only compensates for only a few influencing variables or if it only provides a comparatively rough compensation, then a bigger threshold value must be selected than with an exact compensation of numerous influencing variables.

In a second variant of the invention, which also solves the named task, a method of the same generic type provides that air mass flow supplied to the internal combustion engine is measured, a model for determining the air requirement to be expected at the present operating point is adapted to the air mass flow and a regeneration of the particulate filter is initiated if, after adaptation, the model lies outside the predetermined parameter areas.

According to the invention, a calculation system for the air requirement of the internal combustion engine is adapted to the determined, actual air mass flow. With this variant, the particulate filter is judged to be clogged and a regeneration procedure is initiated if the calculation system leaves the parameter ranges predetermined by the adaptation. This is especially the case if the above named load detection model enters ranges of an implausible behavior of the model. The conclusion can then be drawn that the deviation of the model from the plausible behavior can be put down to a clogging of the particulate filter.

For this variant, the above arguments for interacting between the threshold value and the model exactitude apply analogously. The more influencing variables with higher exactitude are taken into consideration in the load detection model, the tighter the limits of the parameter ranges of the model can be drawn, the leaving of which ranges triggers a cleaning process of the particulate filter.

If the entire system in which the invention is used is equipped with a lambda probe, which regulates the fuel-air mixture by measuring

the residual oxygen content of the exhaust gas to the value for stoichiometric combustion, lambda = 1, thus the signal of the lambda probe and values derived from that, such as from the lambda control, a lambda adaptation, or adaptation information relating to the injection valves, can be used in addition, in order to improve the air requirement calculation and thereby the assessment of the condition of the particulate filter. Misinterpretations with respect to the condition of the particulate filter, as can occur otherwise, for example when there is a leaky intake manifold, are thus effectively avoided.

The air requirement of the internal combustion engine is calculated advantageously in a model that (unadapted) takes an empty or cleaned particulate filter as its starting point in order to obtain a well-defined and reproducible fixed point for the calculation. Further, the calculation of the air requirement and the decision as to whether a regeneration procedure should be initiated can occur at all the operating points or only at one or some predetermined operating points of the internal combustion engine. Then, in the case of the second variant of the invention, the calculation of the air requirement in the remaining operating ranges can be better adapted to the actual current condition of the particulate filter, which on average presents a partly loaded particulate filter.

In a preferred development of the invention, the air requirement of the internal combustion engine is calculated using a model in order to determine the regeneration times, which model takes an empty or cleaned particulate filter as its starting point, and for the control of the internal combustion engine, an air requirement is calculated using a model that takes a partly loaded particulate filter as its starting point. Thereby, in standard operation, it is possible to calculate more exactly the air requirement for the control on average, and the decision as to whether a regeneration procedure is necessary can be based on a more exact current load condition of the particulate filter.

If the two last named procedure methods are combined, then the air requirement for determining the regeneration times is calculated on one or some predetermined operating points taking an empty or cleaned particulate filter as starting point, and the air requirement for the control system of the internal combustion engine is calculated from the other operating points taking a partly loaded particulate filter as starting point. The chosen operating points then permit an assessment of the condition of the particulate filter, the remaining operating ranges a realistic calculation of the air requirement of the engine, for example, for the control based on a load detection model.

In a preferred development of the invention, the calculation system for the air requirement of the internal combustion engine after the implementation of a regeneration procedure of the particulate filter is adapted again.

The invention is explained in more detail below by referring to the drawings by way of example. Thereby is shown in

Fig. 1 a diagrammatic view of an internal combustion engine, in which the method according to the invention is used and

Fig. 2 a flow chart for the implementation of a method according to the invention.

In Fig. 1 an internal combustion engine 10 is shown in diagrammatic view. The internal combustion engine 10 is supplied with fuel 14 by an injection device 12. Combustion air 16 is fed through an intake tract 18. After the combustion of a fuel-air mixture in the internal combustion engine 10, which will not be gone into in more detail, exhaust gases 20 are discharged through an exhaust gas tract 22.

A particulate filter 24 is mounted in the exhaust gas tract 22, which filter filters out particles contained in the exhaust gas 20, in particular soot particles, by storing them. The particulate filter 24 is intermittently cleared of accumulated particles in so-called regeneration procedures. To this end, at a control signal 36 emitted by a control appliance 30, the temperature of the particulate filter 24 is raised above the ignition temperature of the soot particles by means of a heating device. Alternatively, it is possible to adjust the operating point on the internal combustion engine to increase the exhaust gas temperature (broken line). When there is sufficient oxygen concentration in the exhaust gas 20, the soot particles stored in the particulate filter 24 spontaneously burn away.

The control appliance 30 contains an arithmetic unit 32, which calculates the air requirement Lcalc of the internal combustion engine 10 based on different operating parameters jointly referenced by 40 in Fig. 1. A load detection model is used to make the calculation. Such models, which evaluate operating parameters of the internal combustion engine, e.g. speed, pressure in the intake tract, fuel mass supplied, throttle position, operating temperature, etc., and output the air requirement that is to be expected at the operating point, are known to the person skilled in the art. The operating parameters 40 include, for example, the ambient pressure and the operating temperature of the internal combustion engine or such like.

The control appliance 30 is connected to an air mass flow sensor 26 mounted in the intake tract 18, which air mass sensor measures an actual air mass flow flowing through the intake tract and delivers a corresponding signal 38 to the control appliance 30. A measurement Lexp for the actual air mass flow is, on the one hand, transmitted to the arithmetic unit 32 in order, if necessary, to adapt the load detection model to the current conditions. On the other hand, the measurement is supplied together with the calculated air requirement Lcalc to an evaluation unit 34, which unit, as described in more

detail below, decides on the basis of the two values whether a regeneration procedure for the particulate filter 24 should be initiated.

In order to determine the optimal regeneration times for the particulate filter 24, first the load detection system is adapted for an empty or a freshly cleaned particulate filter 24 by means of the arithmetic unit 32 and a threshold value Lthres determined, whose significance will become clear with the description below. In the operation of the internal combustion engine 10, the procedure represented as a flow chart in Fig.2 is then started in a step S10.

In a step S12, with the help of the load detection model, the arithmetic unit 32 first calculates the current air requirement Lcalc of the internal combustion engine 10 for the present operating parameters 40. In a step S14, the actual value Lexp of the air mass flow in the intake tract 18 is determined from the signal 38 of the air mass flow sensor 26 and transmitted to the control appliance 30.

The evaluation unit 34 receives the calculated air mass requirement Lcalc and the measured air mass flow Lexp in the control appliance 30 as input values and, in a step S16, determines the amount of difference between the two values,

$$\Delta L = | \mathrm{Lcalc} - \mathrm{Lexp} |$$

In a step S18, the difference ΔL is compared with a predetermined threshold value Lthres. If the difference is smaller than the threshold value, then no action is taken. The method then goes back to step S12, in which it again calculates the air requirement for the current operating parameters.

If the difference ΔL is greater than the threshold value Lthres the particulate filter 24 is considered blocked and in a step S20, a regeneration of the particulate filter 24 is initiated. The

procedure then ends in the step S22. The implementation of the regeneration itself is known in the prior art and, therefore, will not be explained in detail.

After the regeneration of the particulate filter 24 has been successfully completed, then the load detection model is adapted to the new condition of the particulate filter 24. If this adaptation of the load detection model or of its components delivers an implausible result, then an error message is output. Otherwise the procedure represented in Fig. 2 is begun anew.